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(71) Applicant
Sony Corporation (Japan),
7—35 Kitashinagawa-6, Shinagawa-ku, Tokyo, Japan

(72) Inventors
David Morris Creed,
James Hedley Wilkinson

(74) Agent and/or address for service
D. Young & Co., 10 Staple Inn, London, WC1V 7RD

(54) Decoding digital PAL video signals

(57) Apparatus for decoding an orthogonally sampled, digital PAL video signal comprises a line filter 12, a field filter 13, and a comparator 18 for measuring the cross-talk between luminance and chrominance components of the video signal resulting from movement in the picture represented by the video signal, and a switch arrangement 22 for switching between vertical filtering, temporal filtering, vertical/temporal filtering and horizontal filtering for separation of the chrominance component of the video signal from the luminance component thereof in dependence on the result of the measurement, so as to reduce cross effects resulting from the cross-talk.

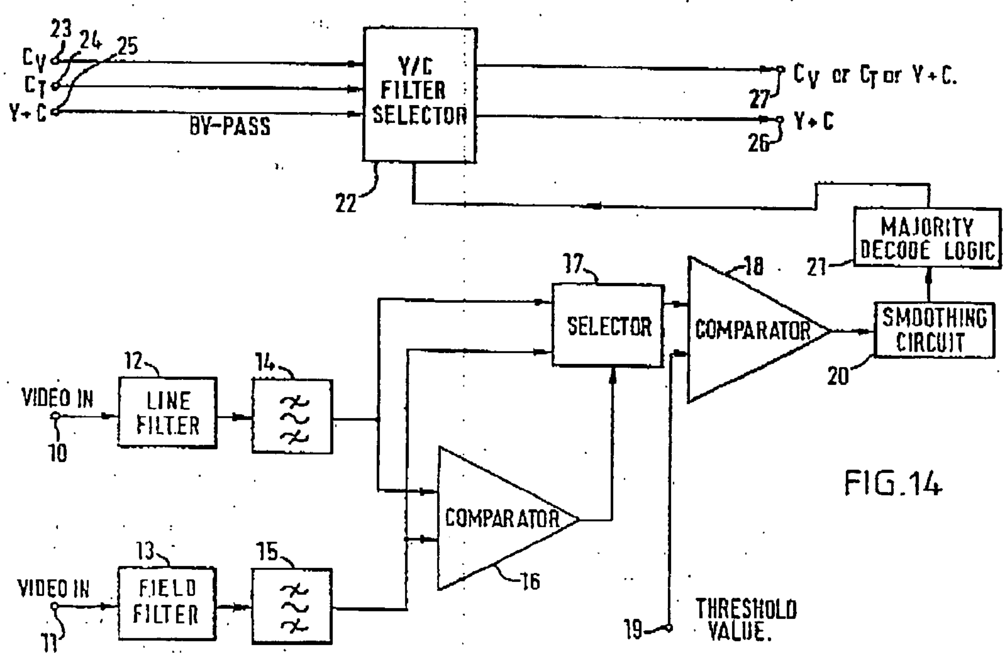

FIG.14

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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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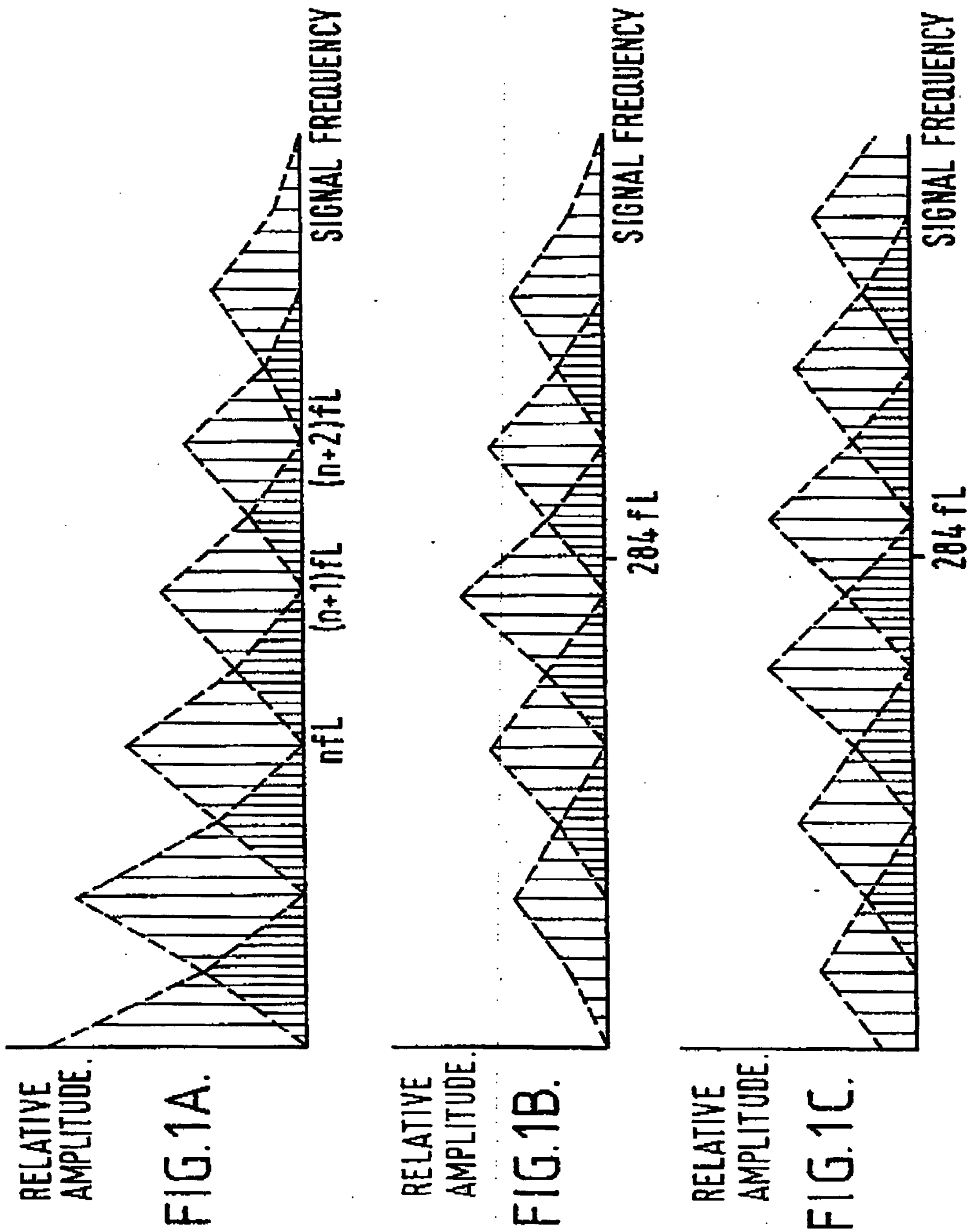

FIG.1A.

FIG.1B.

FIG.1C.

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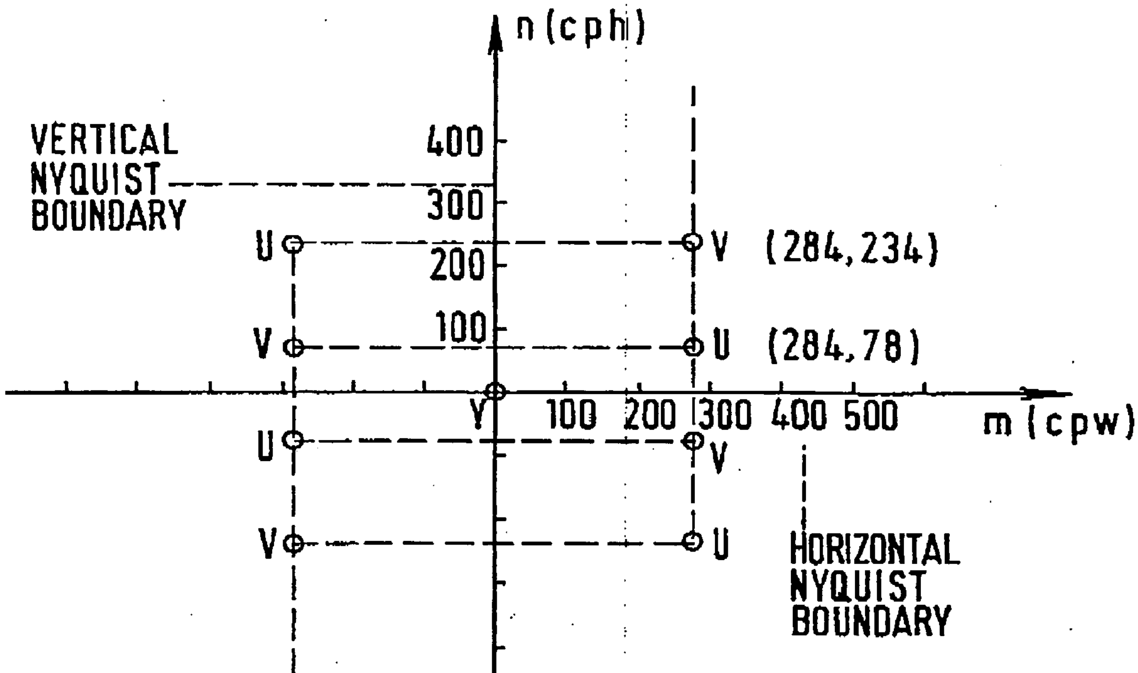

FIG. 2.

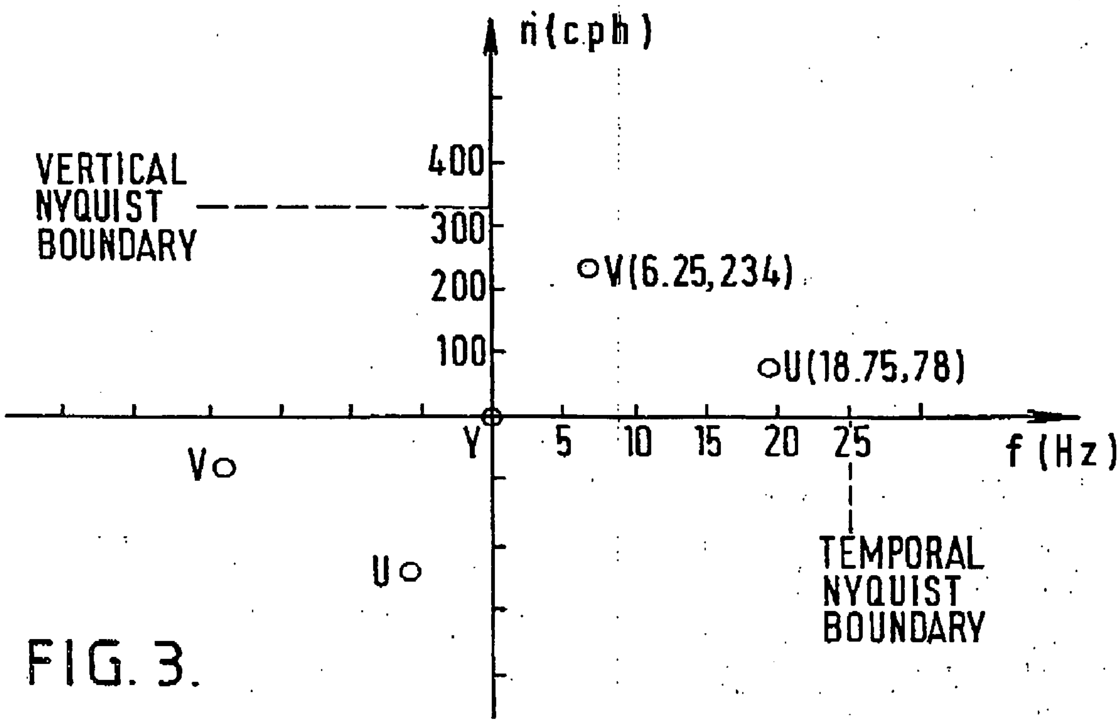

FIG. 3.

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FIG. 4A.
Y
LINE SPECTRUM

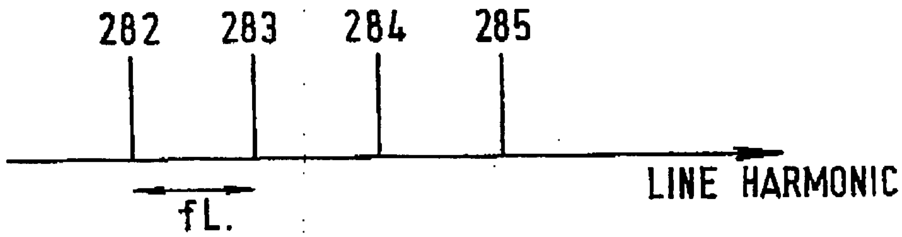


FIG. 4B.
U
LINE SPECTRUM

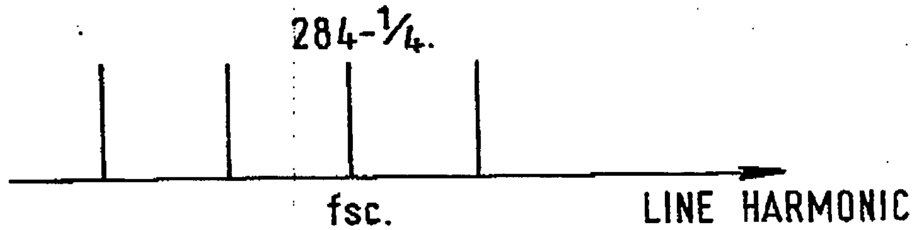


FIG. 4C.
V
LINE SPECTRUM

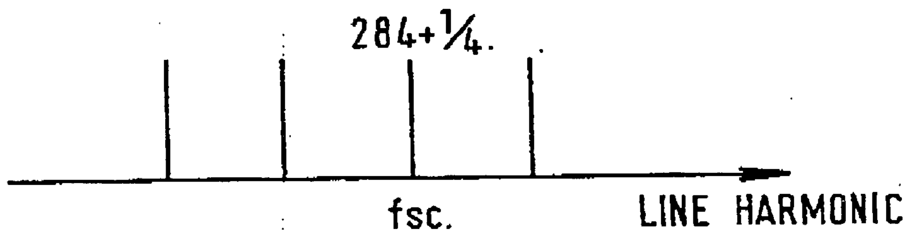


FIG. 4D.
COMBED U
CHANNEL

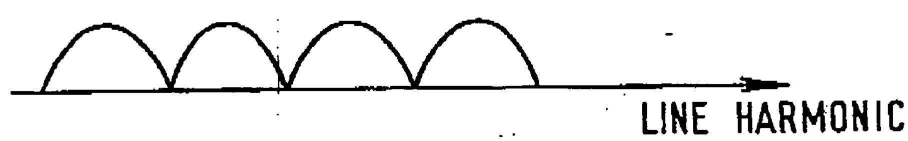
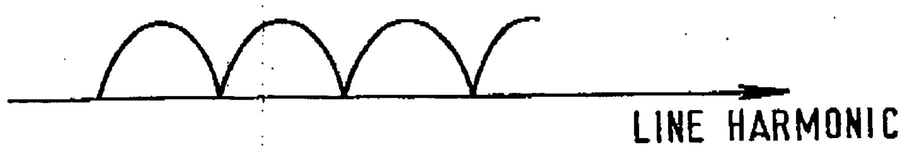


FIG. 4E.
COMBED V
CHANNEL



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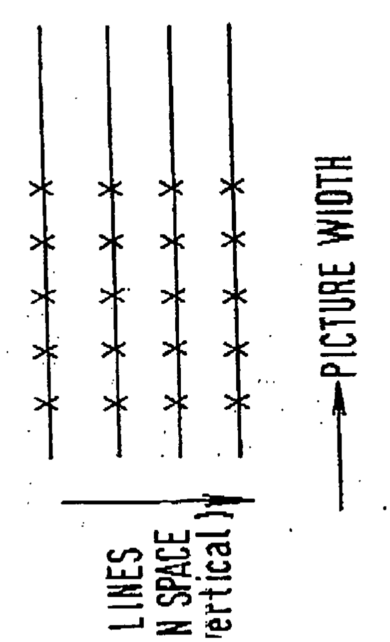

FIG. 5A.

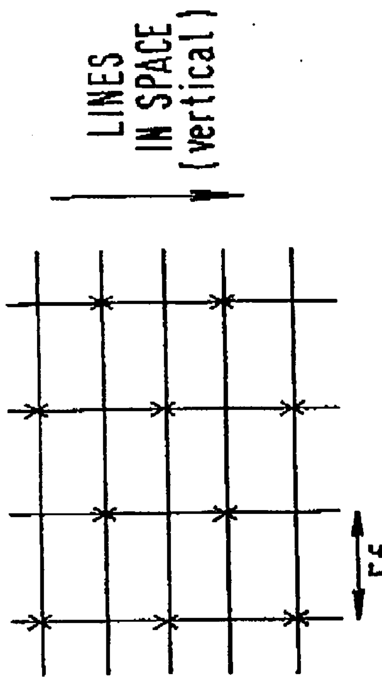

FIG. 5B.

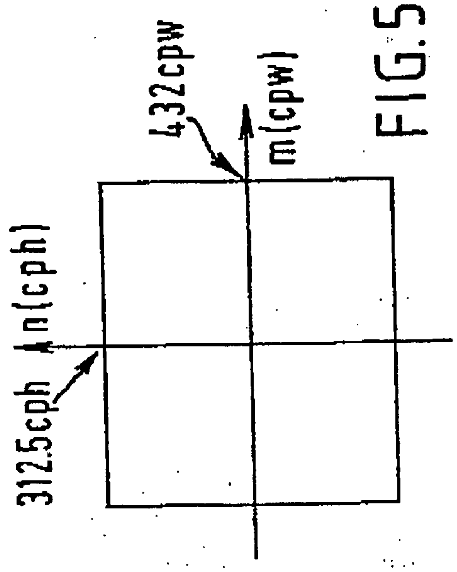

FIG. 5C.

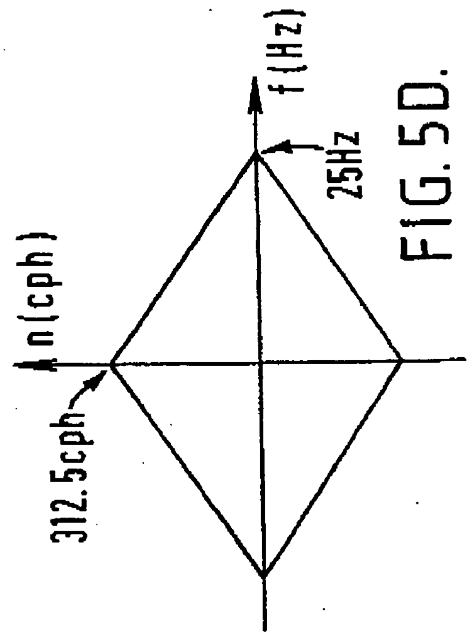

FIG. 5D.

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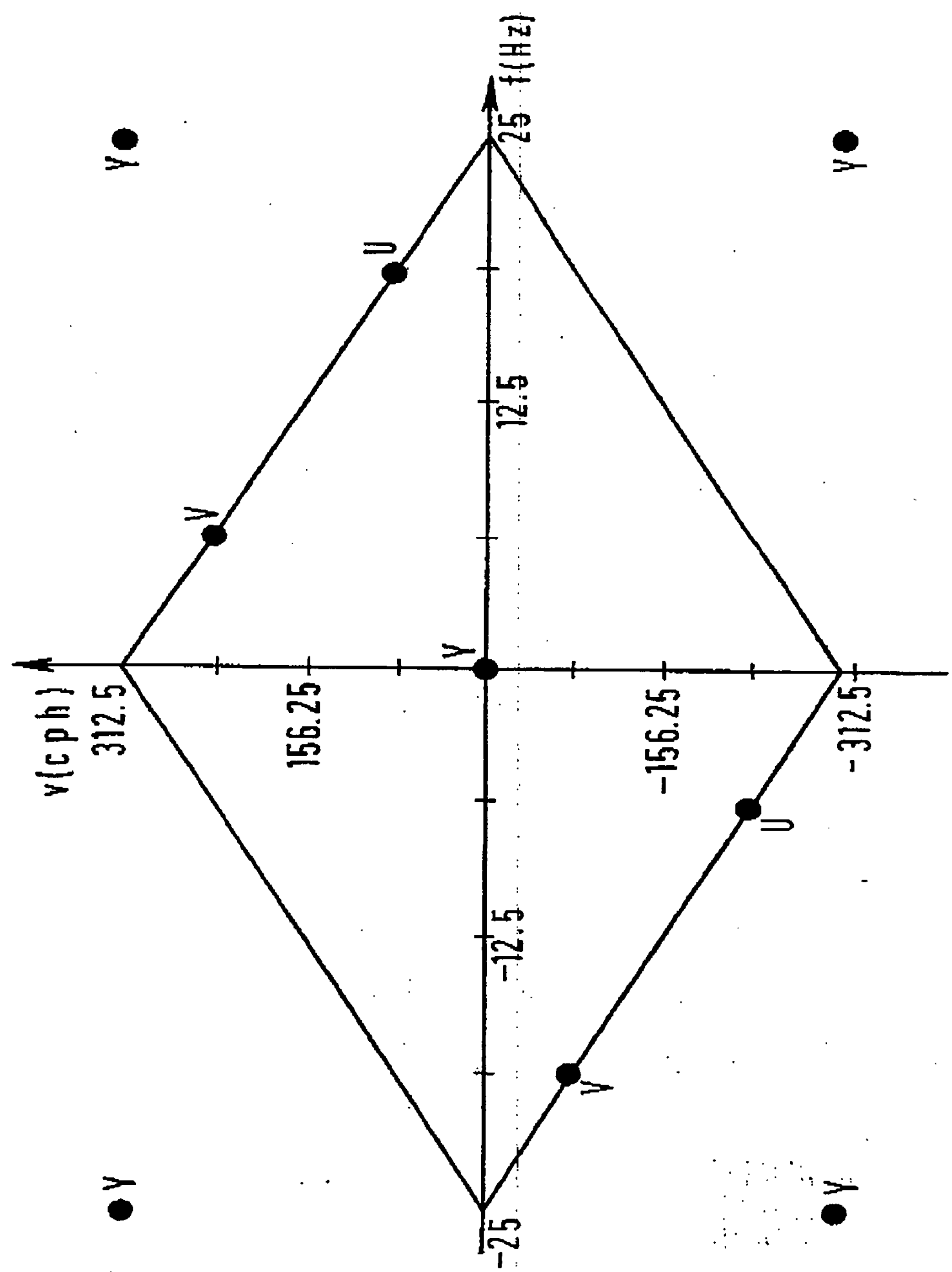

FIG. 6.

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FIG. 7.

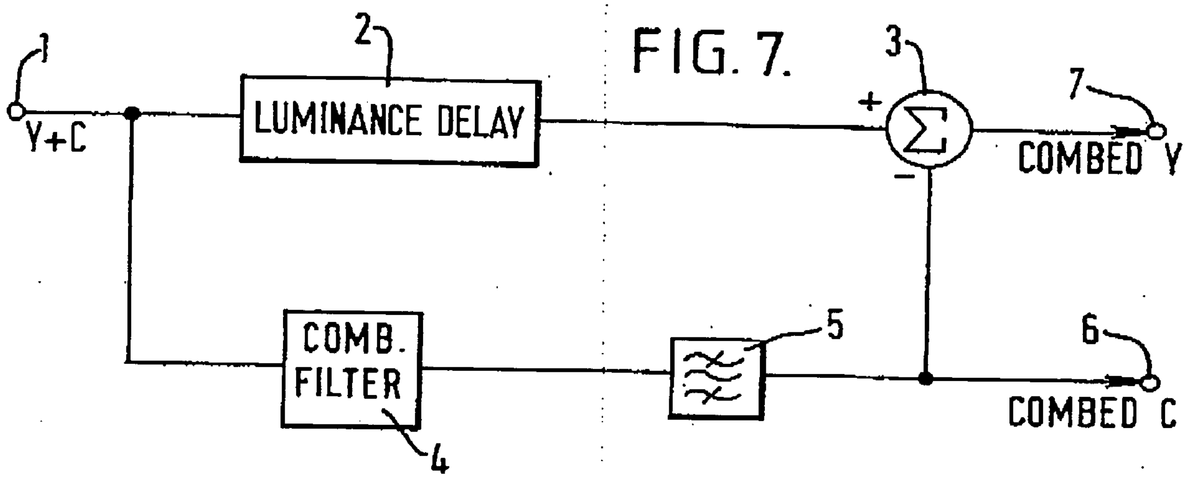
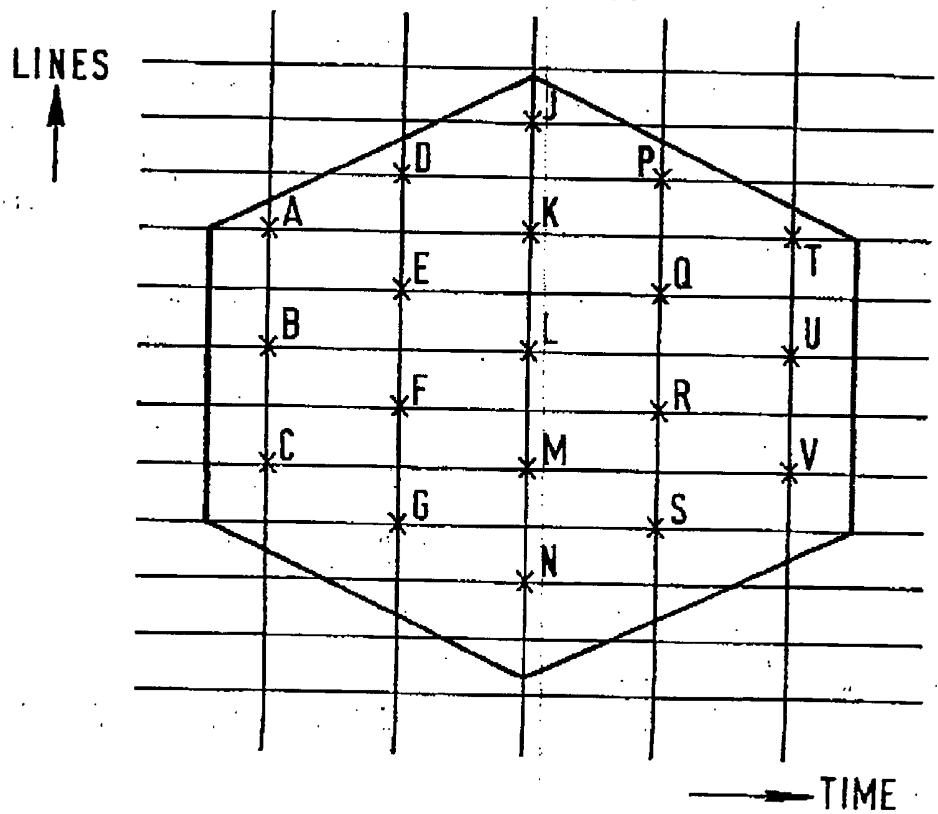


FIG. 8.



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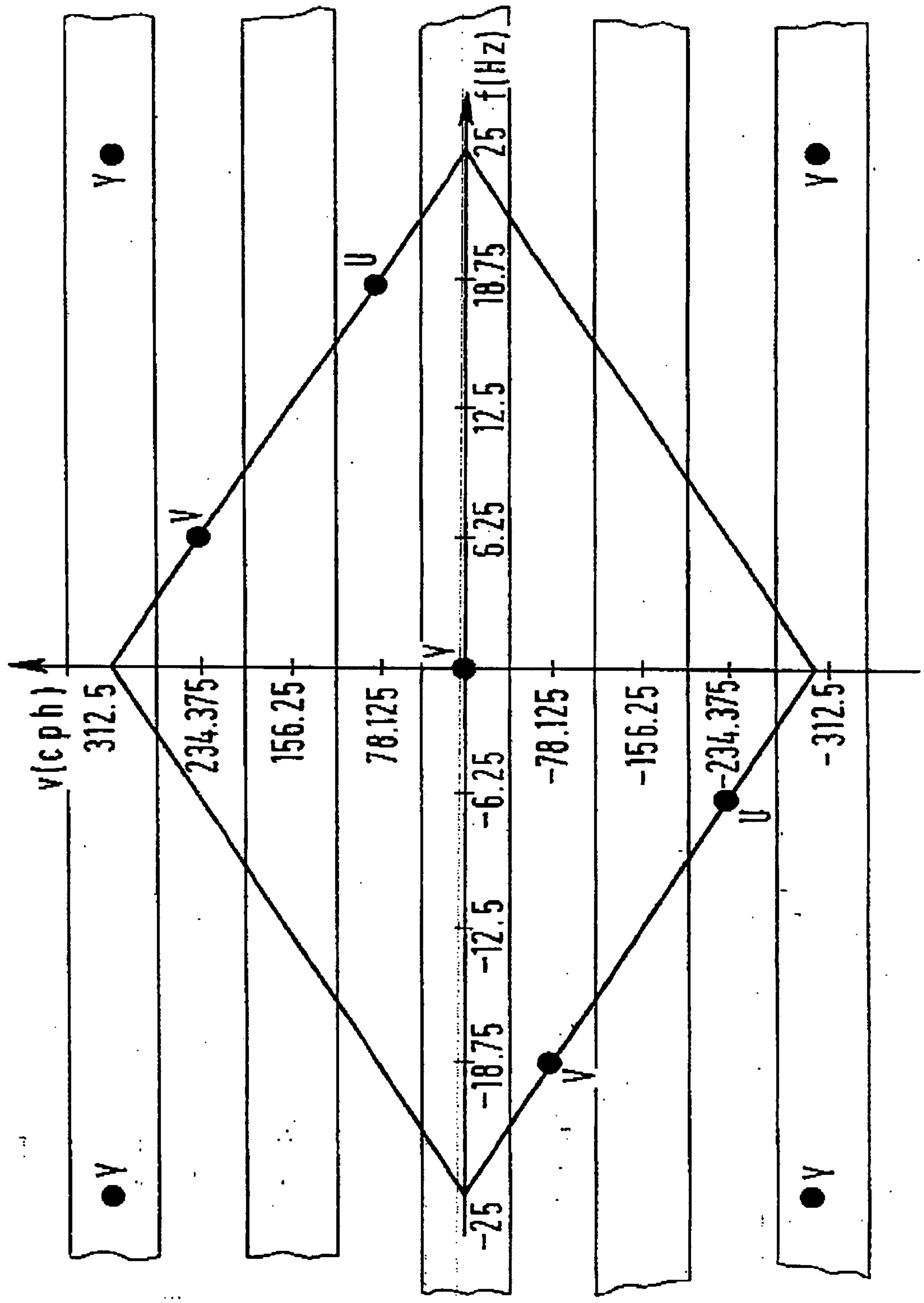

FIG. 9.

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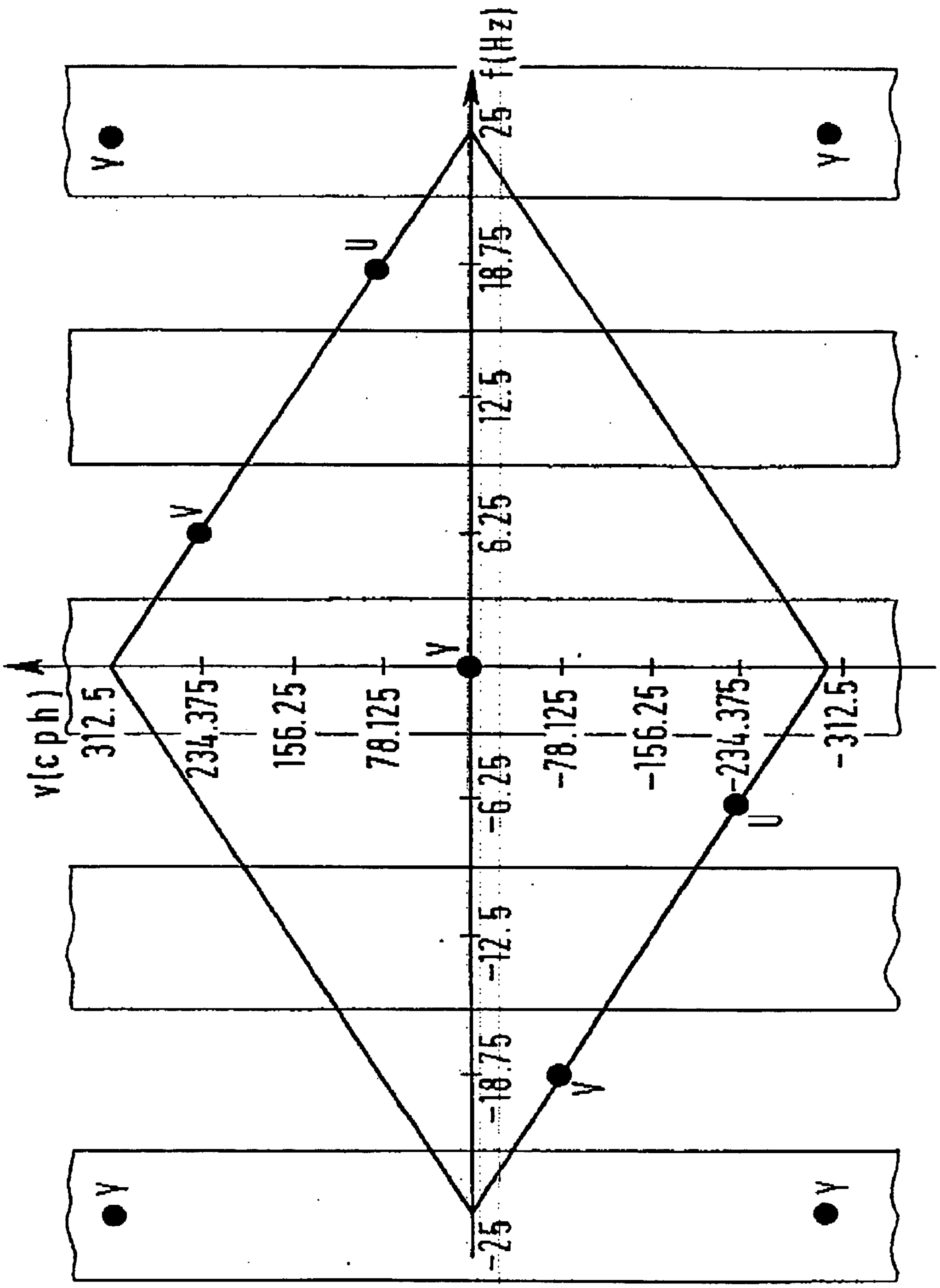

FIG. 10.

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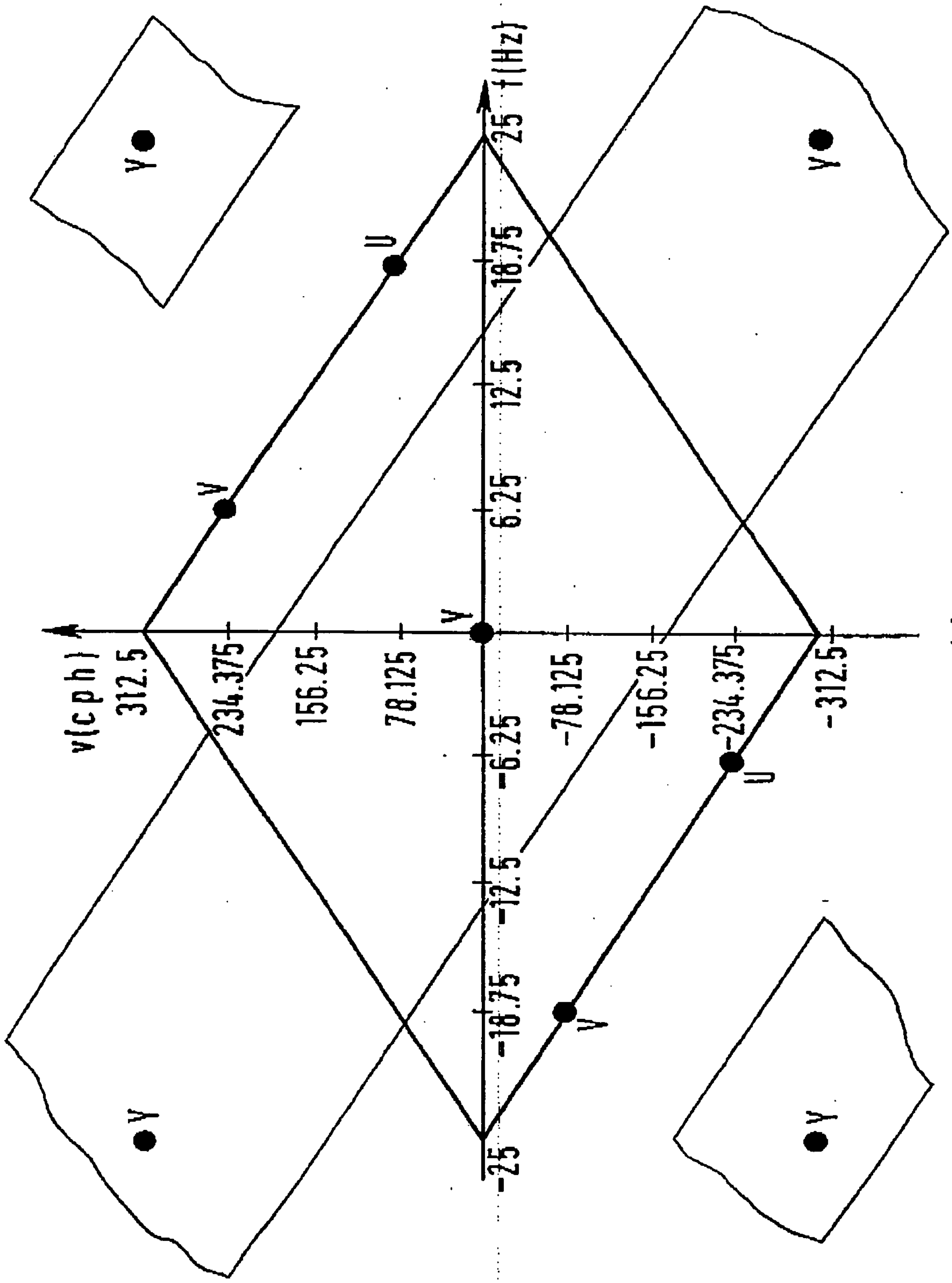

FIG.11.

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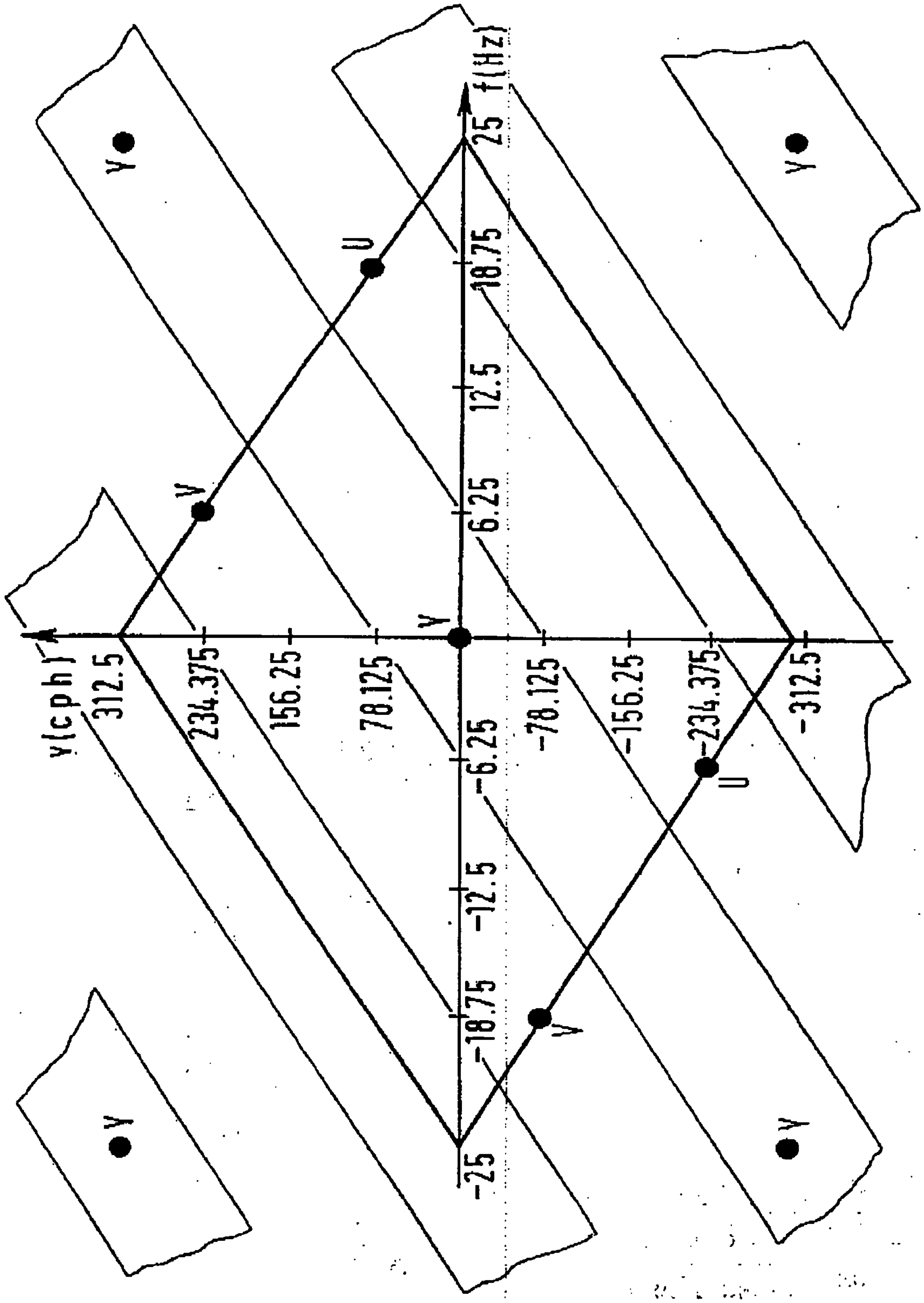

FIG.12.

11/14

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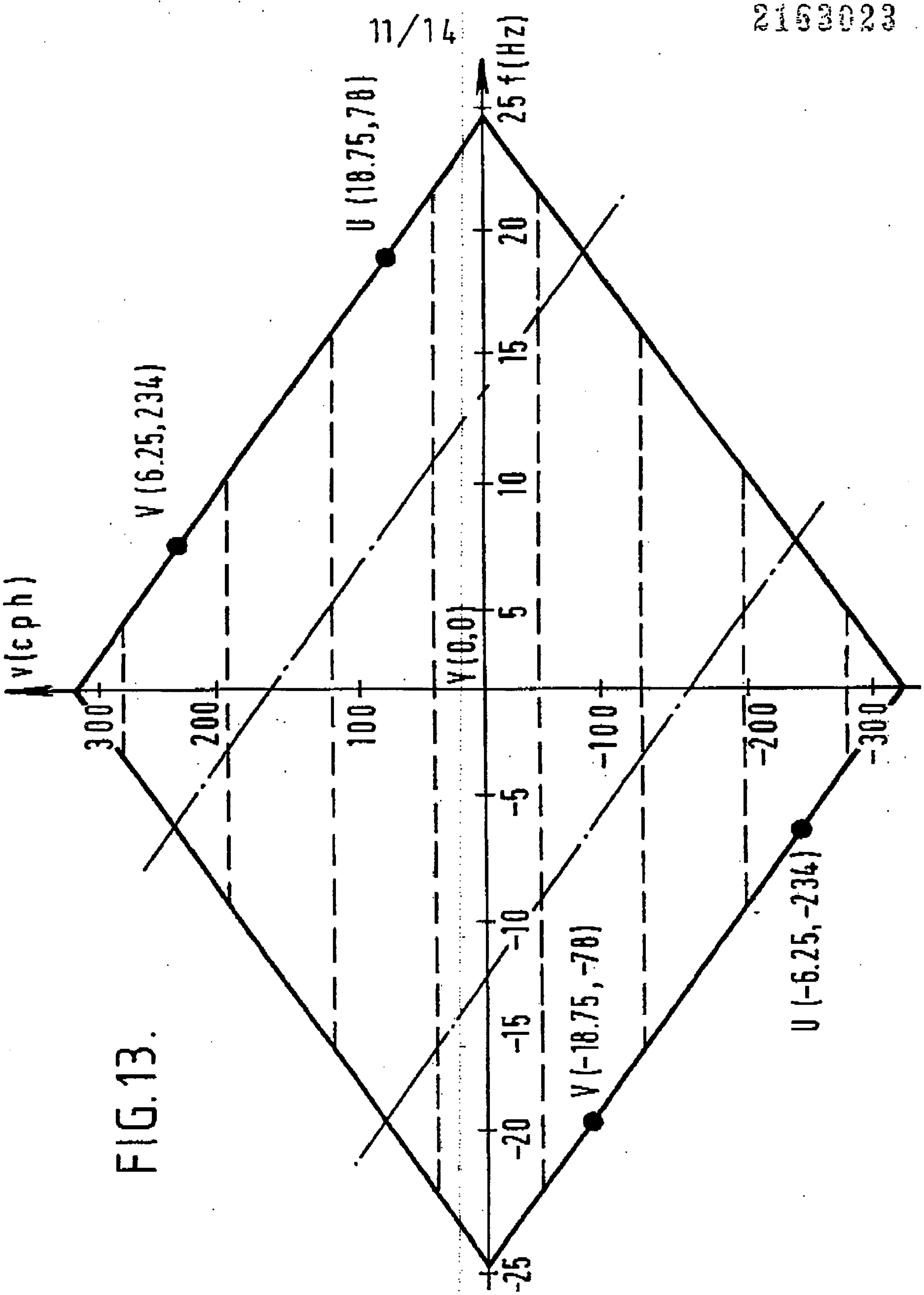

FIG.13.

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12/14

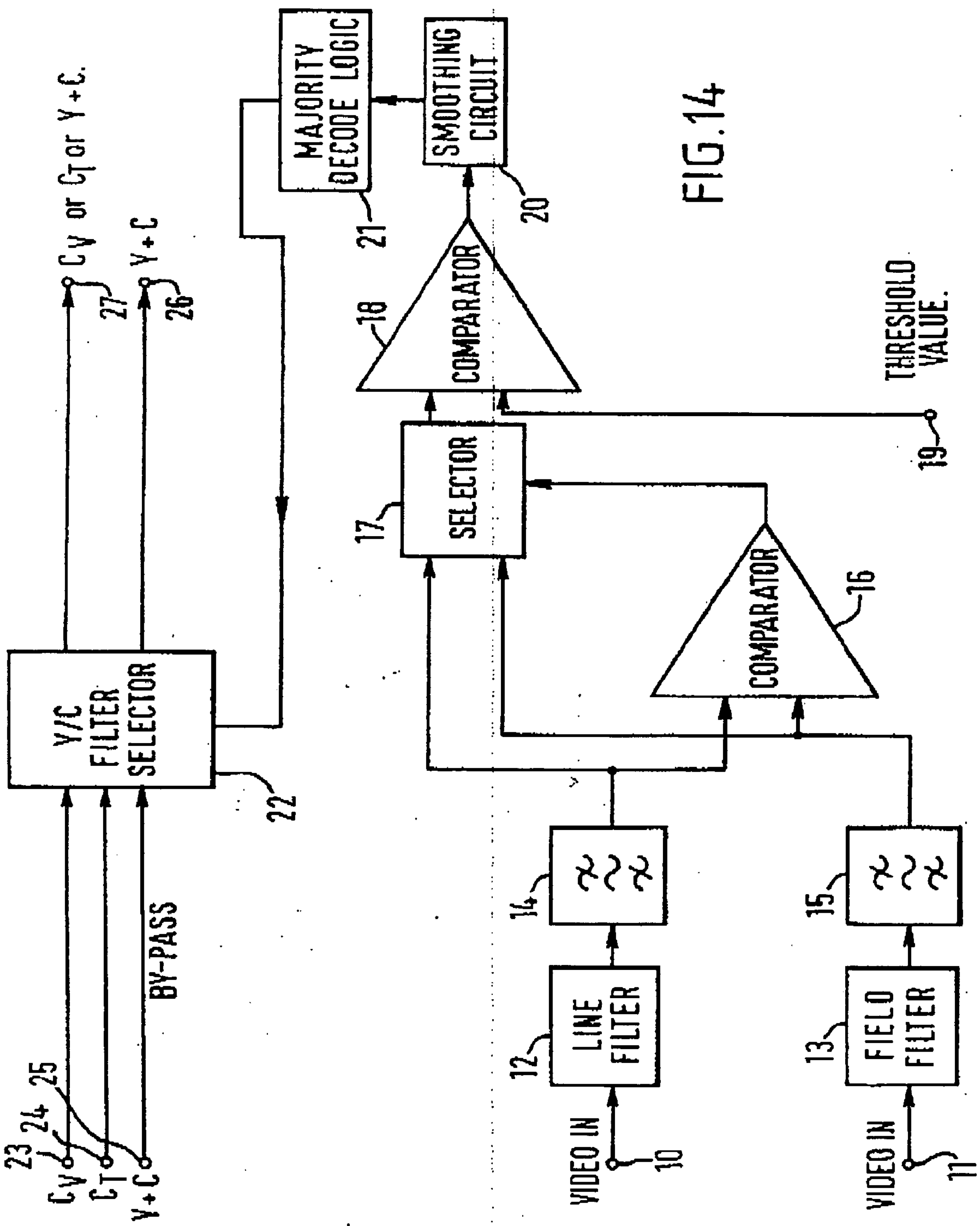

FIG.14

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13 / 14

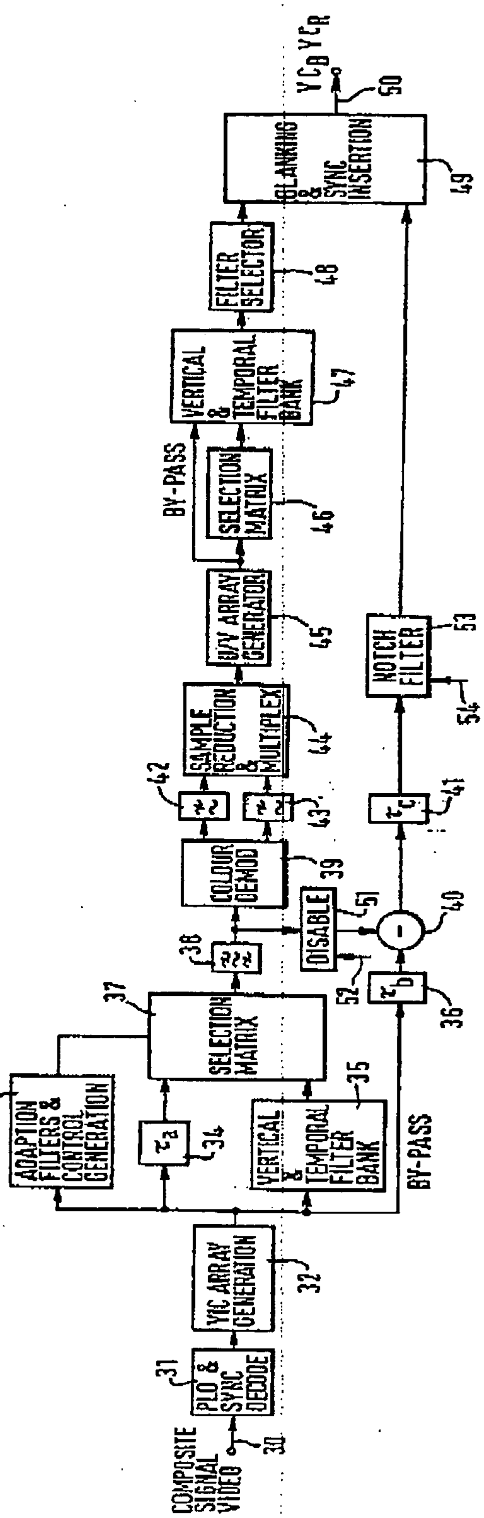


FIG. 15.

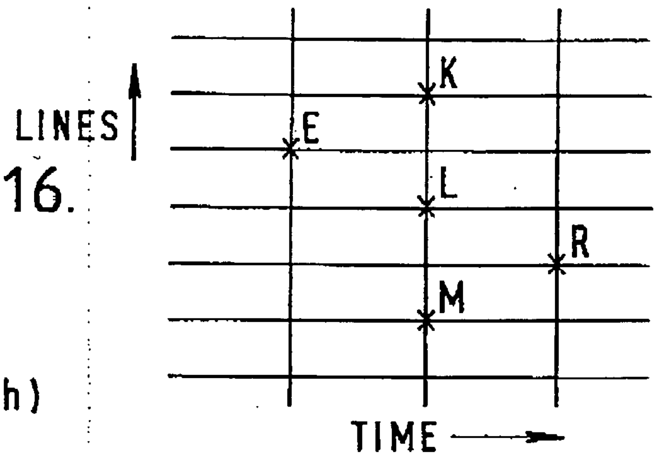


FIG. 16.

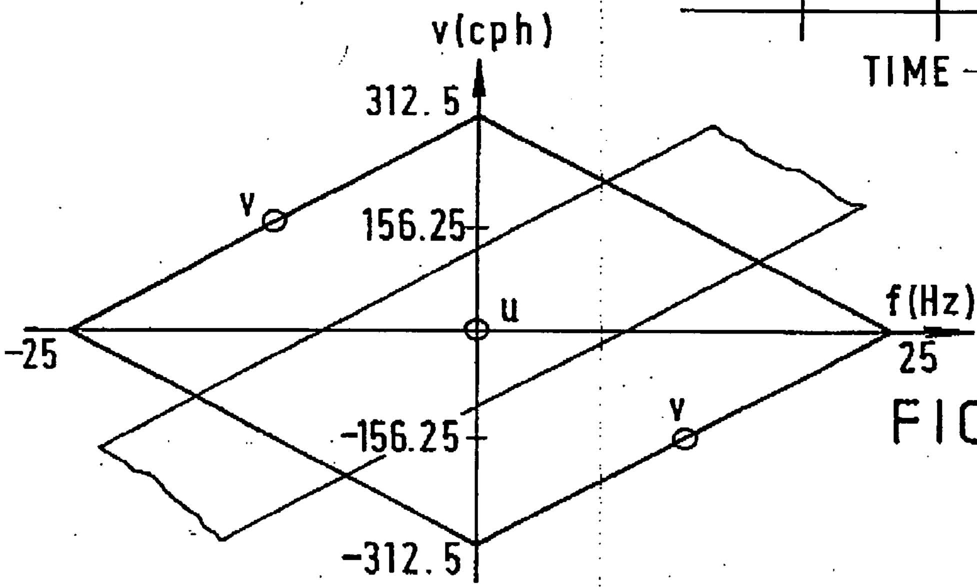
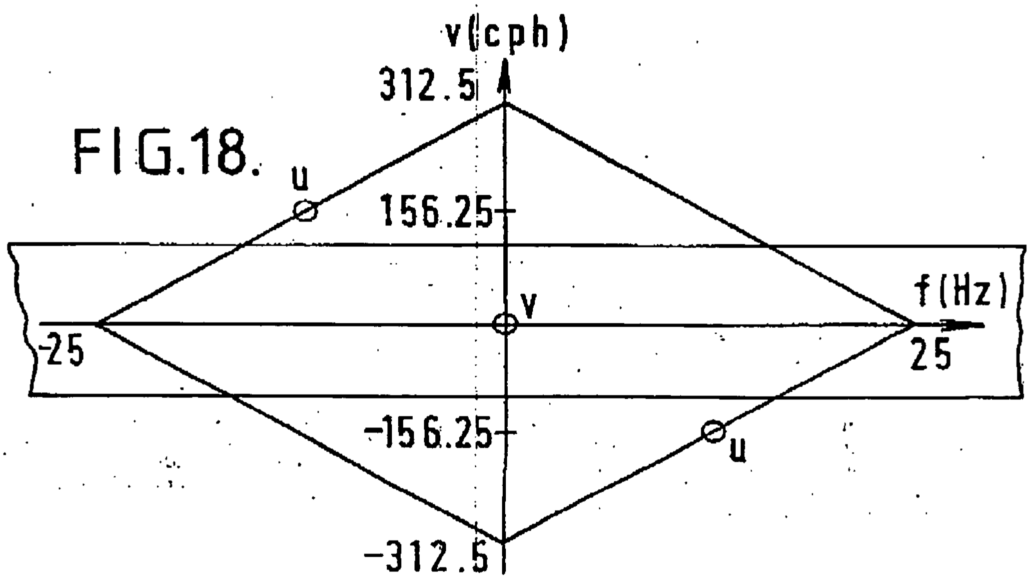


FIG. 17.

FIG.18.



SPECIFICATION

Decoding digital PAL video signals

This invention relates to methods of and apparatus for decoding digital PAL video signals, and more particularly to methods of and apparatus for decoding orthogonally sampled, composite digital PAL video signals.

A substantial amount of effort is currently being directed towards increased use of component digital video systems in television studios, because of the operational and quality improvements that such formats offer over existing composite video systems.

However, current decoding techniques fall well short of the requirements of high quality component video systems, because they comprise between simplicity, a reduction in cross effects and spatial luminance resolution. Where a signal is subjected to many successive decoding and encoding operations, there is a noticeable deterioration in picture quality which negates the advantages of component processing. The inherent stability of digital techniques offers the possibility of an improved performance because it allows accurately defined non-recursive comb filtering to be employed in both decoders and encoders. Moreover, the CCIR 601 standard recommended frequency for luminance sampling an analog PAL video signal is 13.5 MHz, which, being a line locked sampling frequency produces orthogonal sampling structures which aid any filtering process, because it allows the use of line, field and frame-based filtering for separation of the luminance (Y) and chrominance (C) components. Unfortunately in practice some input signals are not suitable for such filtering, in particular where certain spatial components, particularly those resulting from movement in the picture, lead to the re-introduction of cross effects between the luminance and chrominance components when decoding.

According to the present invention there is provided a method of decoding an orthogonally sampled, composite digital PAL video signal, the method comprising the steps of:

measuring the cross-talk between luminance and chrominance components in said video signal resulting from movement in the picture represented by said video signal; and

switching between vertical filtering, temporal filtering, vertical/temporal filtering and horizontal filtering for separation of the chrominance component of said video signal from the luminance component of said video signal in dependence on the result of said measurement, so as to reduce cross effects resulting from said cross-talk.

According to the present invention there is also provided apparatus for decoding orthogonally sampled, composite digital PAL video signals, the apparatus comprising:

means for measuring the cross-talk between luminance and chrominance components of said video signal resulting from movement in the picture represented by said video signal; and

means for switching between vertical filtering, temporal filtering, vertical/temporal filtering and horizontal filtering for separation of the chrominance component of said video signal from the luminance component of said video signal in dependence on the result of said measurement, so as to reduce the cross effects resulting from said cross-talk.

The invention will now be described by way of example with reference to the accompanying drawings, throughout which like parts are referred to by like references, in which:

Figure 1A shows the luminance spectrum of a typical interlaced-scanned still picture;

Figure 1B shows the spectrum of a U chrominance component of the picture corresponding to Figure 1A;

Figure 1C shows the spectrum of a V chrominance component of the picture corresponding to Figure 1A;

Figure 2 shows a two-dimensional spectrum of PAL luminance and chrominance component in horizontal/vertical directions;

Figure 3 shows luminance/chrominance components in vertical/temporal directions;

Figure 4A shows a luminance component line spectrum;

Figure 4B shows a U chrominance component line spectrum;

Figure 4C shows a V chrominance component line spectrum;

Figure 4D shows a comb filtered U chrominance component channel;

Figure 4E shows a comb filtered V chrominance component channel;

Figure 5A shows a sampling structure in space with line locked sampling in vertical and horizontal directions;

Figure 5B shows a sampling structure in vertical and temporal directions showing the effect of line interlacing;

Figure 5C shows the Nyquist boundaries in vertical and horizontal directions corresponding to Figure 5A;

Figure 5D shows the Nyquist boundaries in vertical and temporal directions corresponding to Figure 5B;

Figure 6 shows the central positions of luminance and modulated chrominance components corresponding to a still picture in a vertical and temporal spectrum;

Figure 7 shows in block form a circuit for restricting combed response by inclusion of a band-pass filter;

Figure 8 shows a sample space array;

Figure 9 shows a vertical/temporal characteristic for a line based comb filter;

Figure 10 shows a vertical/temporal characteristic for a 625-line comb filter;

Figure 11 shows a vertical/temporal characteristic for a 312-line comb filter;

Figure 12 shows a vertical/temporal characteristic for a 313-line comb filter;

Figure 13 shows the vertical/temporal characteristic for a pair of adaption filters;

Figure 14 shows in block form a circuit for

adaptive selection of decoding of a digital PAL video signal;

Figure 15 shows in block form a PAL decoder system incorporating adaptive selection of the decoding;

Figure 16 shows a sample space array;

Figure 17 shows the vertical/temporal characteristic of a field-based U/V separation filter; and

Figure 18 shows the vertical/temporal characteristic of a line-based U/V separation filter.

In order to understand the present invention, the spectral characteristics of a PAL composite signal in three-dimensional space will first be discussed, followed by a brief consideration of standard PAL decoding techniques. Then PAL decoding using digital techniques to which the present invention can be applied will be considered.

A PAL signal occupies a three-dimensional spectrum having horizontal, vertical and temporal components, in which well defined centres of spectral energy for the luminance and U and V chrominance components can be specified.

Consider first the effect of line scanning upon a picture. It can be shown that for an interlaced system of scanning, the translation of spatial frequencies in two-dimensional space to an equivalent signal frequency is governed by the following equation

$$v = fL(m-2n/N) \qquad (1)$$

where m is the number of cycles per picture width (cpw), n is the number of cycles per picture height (cph), N is the total number of scanning lines in the picture, fL is the line frequency, and v is the equivalent signal frequency.

Equation (1) does not take any account of movement within the picture, which will be referred to below. It can also be shown that both the luminance and the chrominance energy are concentrated on line harmonics with sidebands separated from the harmonics at intervals corresponding to the field frequency. In particular, it can be shown statistically that most of the energy within a picture occurs at low values of m and n, indicating that there is reduced energy at and around line harmonics as the spatial frequency increases. The scanning action, which will translate spatial to signal frequencies, is in effect sampling the picture content vertically, in this case at a rate of N samples per picture height. Sampling theory specifies that for alias free reproduction of the base band spectrum, the sampling rate must be a minimum of twice the signal bandwidth. This imposes a vertical bandwidth restriction on the signal of N/2, that is 312.5 cph for a 625-line system.

Figure 1A shows the luminance spectrum of a typical interlaced-scanned still picture, the ordinates representing relative amplitude of the luminance component and the abscissae representing signal frequency. It should be noted that there is no confusion between adjacent line harmonics, this being a consequence of N being odd.

The base band U chrominance component can be analysed in exactly the same way, but it is spatially shifted due to the double side band suppressed carrier modulation which is used. Thus the frequency fsc of the sub-carrier is given by:

$$fsc = (284 - \tfrac{1}{4})fL \qquad (2)$$

Since the sub-carrier frequency is specified to be 284 times the line frequency minus one-quarter of the line frequency (a temporal offset fp being ignored) then the U chrominance component will be centred on frequencies with the same offset below multiples of the line frequency. This is illustrated in Figure 1B which shows the spectrum of the U chrominance component.

The exact nature of the V chrominance component spectrum is more complex due to the phase alternation. This phase alternation is line by line, so there is a half-line (½fL) offset in the V chrominance component. This results in centres of V chrominance spectra being displaced by ½fL. The resulting V chrominance component has centres at frequencies one-quarter of the line frequency fL above the line harmonics. This is seen in Figure 1C which shows the spectrum of the V chrominance component.

The same thing can be illustrated in a rather different way by deriving the positions of the luminance and U and V chrominance components and showing them as illustrated in Figure 2, which is a two-dimensional spectrum of the PAL luminance and modulated chrominance components. In this figure the ordinates represent cycles per picture height and the abscissae represent cycles per picture width. This figure illustrates that the sub-carrier introduces a spatial offset to the base band U and V components. Moreover, it indicates that filtering in a horizontal direction and filtering in a vertical direction can be used for the separation of the luminance and chrominance components.

However, it is additionally necessary to consider the effect of movement in the picture. For a picture with no movement, the luminance information is fixed on a frame-by-frame basis, and it would not therefore be expected that any temporal luminance energy should exist until movement occurs in the picture. The situation is, however, different for the U and V chrominance components when the 25 Hz (fp) offset introduced into the sub-carrier frequency is considered. Thus, the exact relationship is:

$$fsc = (284 - \tfrac{1}{4})fL + fp \qquad (3)$$

Using this, it is possible to derive spectral centres for the U and V chrominance components incorporating temporal offset. This is illustrated in Figure 3, which shows the luminance and chrominance components in vertical and temporal space at a horizontal frequency of approximately 284 cpw. In this case the ordinates represent cycles per picture height and the abscissae represent frequency. By considering the temporal direction, it is again possible to specify a boundary for alias free reproduction. Since a picture can also be considered

to be temporally sampled at the field rate, then this boundary as defined by the Nyquist criteria occurs at half the field rate, that is to say 25 Hz for a 50 field per second PAL signal.

The purpose of any PAL decoding technique is to separate as efficiently as possible, and with the minimum of degradations, the luminance and chrominance components of the composite signal. Having achieved this, it must then accurately demodulate the chrominance information to the base U and V locations. Standard decoding techniques compromise between simplicity of luminance/chrominance separation and so-called cross effects left as a result of inadequate decoding.

Simple PAL decoding achieves separation of luminance and chrominance components merely by introducing a notch filter in the luminance channel and a band-pass filter in the chrominance channel. The notch filter is centred at the sub-carrier frequency fsc to attenuate the main chrominance energy. The width of the notch is a compromise between loss of high frequency luminance energy, this high frequency energy being essential for the reproduction of fine detail, and reduction of the sub-carrier component in the luminance channel. The band-pass filter to separate out the chrominance energy cannot distinguish between the chrominance and luminance components within its band. Consequently cross effects are present in both channels. Colour cross-talk in a luminance channel causes cross luminance effects which show themselves as so-called sub-carrier crawl at horizontal colour transitions. A potentially more disturbing effect is due to luminance components being demodulated as colour, leading to cross colour which shows as shimmering areas of colour in locations of fine luminance detail. A reduction in the visually annoying cross colour can be achieved by delay line decoding, which utilises a form of electrical averaging to achieve U/V chrominance component separation. The delay line separates the U and V sub-carrier components before they are synchronously demodulated by the reference sub-carriers. This process is based on the assumption generally true for most picture content, that the same signal is transmitted on successive lines. This would lead to complete cancellation of the U chrominance component in the V channel and vice versa. The overall effect of this delay line separation is to produce a comb filter characteristic for U and V which is illustrated in Figures 4A to 4E. In these figures, line harmonics are plotted along the abscissae. Figures 4A to 4C show the lines spectra for Y, U and V components respectively, and Figures 4D and 4E show the comb filtered U and V chrominance component channels respectively.

As mentioned above, recent standardization formats use a line locked luminance sampling frequency of 13.5 MHz, and the use of such a frequency results in orthogonal sampling structures in which all the samples in all the lines within a field of the picture are disposed orthogonally with respect to each other. Figure 5A shows the sampling structure in vertical and horizontal space with line locked sampling, and Figure 5B shows the sampling structure when the temporal effect due to line interlace is taken into account. Ff is the field frequency, the field period being 20 milliseconds for a 50 field per second system.

The sampling structure of Figure 5A results in a rectangular Nyquist boundary as indicated in Figure 5C. The sampling frequency of 13.5 MHz produces 864 samples per horizontal line so there is a Nyquist bandwidth of 432 cpw. The rectangular boundary for alias free reproduction is bounded vertically at 312.5 cph as explained above.

The Nyquist boundary in the vertical and temporal directions corresponding to Figure 5B is shown in Figure 5D and is rhombic in nature, the points of the rhombus being at 25 Hz in the temporal direction and 312.5 cph in the vertical direction.

Figure 6 shows the positions of the stationary luminance and modulated chrominance components vertically and temporally. The spectral positions of the components are shown in relation to a horizontal frequency of approximately 284 cpw. In other words, the diagram shown in Figure 6 is a slice through the three-dimensional spectral array at a horizontal frequency of approximately 284 cpw.

A reduction in cross effects can be achieved in decoding by employing comb filtering for luminance/chrominance component separation, based on line delays. In effect this technique uses the vertical offsets of the U and V chrominance components (see Figure 6) as a basis for a vertical filter characteristic. Since, however, the U and V chrominance components occupy a well-defined horizontal spectrum, it is not necessary to employ vertical filtering over the entire horizontal bandwidth, so the vertical comb filtering is horizontally bounded by the incorporation of a band-pass filter. This is illustrated in the circuit of Figure 7 to which reference is now made.

The input signal comprising the luminance and chrominance components is supplied by way of an input 1 to a first path comprising a delay circuit 2 and an adder 3, and to a second path comprising a comb filter 4 and a band-pass filter 5. The delay introduced by the delay circuit 2 is selected such that the delay in the two paths is the same. The comb filter 4 extracts the chrominance components and those chrominance components falling within the pass band of the band-pass filter 5 are supplied to an output 6. Additionally, these filtered chrominance components are supplied to the adder 3 where they are subtracted from the signal supplied thereto by the delay circuit 2, so that the adder 3 supplies combed luminance components to an output 7.

Figure 8 shows a sample space array, the samples shown corresponding to five shields of a video signal, and in each field of a frame the samples are arranged orthogonally. A total of nineteen samples are shown designated A to G, J to N and P to V, and these designations will be used below for specifying filter characteristics.

Figure 9 shows the vertical/temporal characteristic of a line based vertical/temporal comb filter based on sample points in the array of Figure 8 and using K/2—M/2. This shows the filter

characteristic at around the true sub-carrier frequency, the broken-ended rectangles indicating regions of chrominance signal rejection. Thus, so long as the spectral energies of the U and V chrominance components are concentrated at the centres shown there is good selection by this filter of the chrominance components. A required filter for the luminance component is the complement of this.

The filter characteristic of Figure 9 based on K/2—M/2 is not truly symmetrical and results in a group delay error. An alternative vertical/temporal filter which gives a similar characteristic but with no group delay problem is based on J/4+L/2−N/4.

Referring now to Figure 10, this shows the vertical/temporal characteristic for a 625-line comb filter based on sample points in the array of Figure 8 using B/2−U/2. Again, the broken-ended rectangles indicate the regions of chrominance signal rejection. Non-recursive filters based on field and frame delays can give excellent results for the separation of luminance and chrominance components. In particular, filters based on frame delays give responses which act in the temporal plane achieving perfect separation in the case of pictures without movement, where luminance energy is concentrated on a straight line parallel to the vertical axis at 0 Hz and ±25 Hz. Similarly, the chrominance energy is concentrated on straight lines parallel to the vertical axis at 6.25 Hz and 18.75 Hz for the V and U colour components respectively. Although Figure 10 shows the characteristic for such separation based on a frame delay (625 line delay), other such filters are possible using longer time delays, in particular a truly symmetrical filter using a four frame delay, but are less suitable for practical use because of the very large amount of hardware necessary for the required storage.

Referring to Figure 11, this shows the vertical/temporal characteristic for a 312-line comb filter based on sample points in the array of Figure 8 using −F/4+L/2−Q/4. The filter corresponding to Figure 11 is a compromise which uses a field delay and in so doing compromises between vertical and temporal resolution in order to achieve the required good separation. The broken-ended rectangles indicate the regions of chrominance rejection.

Likewise, Figure 12, to which reference is now made, shows a vertical/temporal characteristic for a 313-line comb filter, based on sample points in the array of Figure 8 and using E/2−R/2. Again, the broken-ended rectangles indicate the regions of chrominance rejection. In this case an alternative filter which gives a truly linear phase response uses −A/4+L/2−V/4.

It should, however, be noted that separation of the luminance and chrominance components using vertical or temporal filters having characteristics as illustrated in Figures 9 to 12 will inevitably result in problems of luminance and chrominance cross effects when there is movement in the picture. This is because in that case the distinction between luminance and chrominance components in the frequency interleaved spectra is reduced, due to the spread of energy from the centres marked. This problem can be alleviated to some extent by limitation of the horizontal luminance bandwidth at the encoder, but this results in noticeably less sharp pictures. Embodiments of the present invention therefore make use of adaptive decoding whereby the mode of luminance/chrominance separation used is determined in accordance with the content of the picture, and in particular whether there is movement within the picture.

In order to decide on the mode of luminance/chrominance separation to be selected, the cross-talk has to be detected, and this is done by means of further filters referred referred to herein as adaption filters. Figure 13, to which reference is now made, shows the vertical/temporal characteristic and in particular the axes of the spectral peaks of a diagonal (312 line based) adaption filter based on sample points in the array of Figure 8 and using F/2—Q/2, these axes being indicated by the diagonal lines made up of alternating long and short dashes, and of a vertical adaption filter based on sample points in the array of Figure 8 using J/2—N/2, these axes being indicated by the horizontal broken lines. On consideration of this characteristic it will be seen that these adaption filters satisfy the requirement that each filter has its nulls situated at the spectral centres of both luminance and chrominance signals for cases where there is no movement in the picture. In an absolutely ideal situation with a picture having no movement, therefore, neither of the adaption filters would supply a large output. However, as soon as there is movement within the picture, the spectral centres of the luminance and chrominance signals will begin to spread and both the adaption filters will supply outputs, the levels of these outputs depending on the degree of movement and hence the degree of spreading of the luminance and chrominance spectral centres. By comparison of the outputs of the adaption filters, therefore, the optimum mode of luminance/chrominance separation can be selected.

It would be possible to provide a third adaption filter operating in a purely temporal direction to provide a further means of detecting the cross-talk between the luminance and chrominance components, but such a filter requires eight field stores and in general therefore the use of such a third adaption filter is not justified because of the substantial additional amount of hardware that it requires. Normnally, therefore, only the diagonal and vertical adaption filters referred to above are used, and in situations where these two adaption filters give an indeterminate comparison, then the standard PAL decoding mode using horizontal filters is used. Thus it is to be noted that neither of the adaption filters can distinguish whether it is the luminance or the chrominance component which is producing the cross-talk, and in any case in those situations where luminance energy is present in the chrominance frequency band or vice versa, complete separation is in any case not possible.

This will now be described in more detail with reference to Figure 14 which shows in block form a circuit for adaptively selecting the form of decoding to be used for an incoming PAL video signal.

The incoming digital video data, that is to say comprising the luminance and chrominance components is supplied by way of inputs 10 and 11 to adaption filters 12 and 13 respectively. The adaption filter 12 is a vertical line filter based on J/2—N/2, and the adaption filter 13 is a 312-line field filter based on F/2—Q2.

The adaption filters 12 and 13 enable a measure of the luminance/chrominance cross-talk to be obtained as described above.

The outputs of the filters 12 and 13 are supplied by way of respective band-pass filters 14 and 15 to respective inputs of a comparator 16. The band-pass filters 14 and 15 are provided merely to make the adaption filters 12 and 13 operate over the same horizontal range of frequencies as that over which the main luminance/chrominance separation comb filters operate. The output of the comparator 16 is supplied to a selector 17 which also receives the outputs of the band-pass filters 14 and 15 and supplies one of these outputs to a further comparator 18 in dependence on the control signal supplied by the comparator 16. A second input of the comparator 18 receives a threshold value from an input 19. The comparator 18 compares the level of the selected signal passed by the selector 17 with the threshold value, and if the selected value is such that a predetermined maximum permissible cross-talk level is exceeded, then a by-pass mode referred to below is used in place of the vertical or temporal decoding for luminance/chrominance separation.

The output of the comparator 18 is supplied by way of a smoothing circuit 20 to a majority decode logic circuit 21, the output of which is connected to a luminance/chrominance filter selector 22. As the circuit is operating digitally, sample by sample, it is theoretically possible for the output of the further comparator 18 to switch the selector 22 sample by sample. However, such rapid switching may be subjectively unacceptable in the resulting picture, so the switching is smoothed in the horizontal direction by the elements 20 and 21 which have the effect of ensuring that switching does not occur more frequently than once every few samples, for example, once every five samples.

The filter selector 22 has inputs 23, 24 and 25 to which the chrominance component C_V derived from a vertical filter, the chrominance component C_T derived from a vertical/temporal field filter (312-line filter), and the luminance plus chrominance components respectively are supplied. The input 25 is supplied for use in the by-pass mode, that is, when the comparator 18 indicates that the permissible cross-talk level is exceeded, and when this mode is selected the filter selector 22 passes the luminance plus chrominance components unchanged from the input 25 to an output 26, and also supplies the luminance plus chrominance components after band-pass filtering to an output 27. At other times, the filter selector 22 operates in dependence on the output of the comparator 18 and selects the chrominance component C_V derived by the vertical filter, or the chrominance component C_T derived by the vertical/temporal filter, for supply to the output 27, in dependence on which is indicated by the comparator 18 as resulting in the lower cross-talk.

Figure 15 shows in block form a complete PAL decoder system incorporating adaptive selection of the decoding. The input composite signal is orthogonally sampled digital form is supplied by way of an input 30 and a phase-locked oscillator and synchronizing code decoder 31 to a luminance/chrominance array generator 32. The array generator 32 comprises four line stores and four field stores, and is operative to derive an array of samples as indicated in Figure 8. The output of the array generator 32 is connected to an adaption filter and control generator arrangement 33, to a first delay circuit 34, to a vertical and temporal filter bank arrangement 35, and to a by-pass path comprising a second delay circuit 36. In terms of Figure 14, the output of the first delay circuit 34 provides the luminance plus chrominance components for supply to the output 27 in the by-pass mode, while the vertical and temporal filter bank arrangement 35 provides the signals for the inputs 23 and 24, and the second delay circuit 36 provides the signal for the output 26. The adaption filter and control generator arrangement 33 corresponds broadly to the elements 10 to 21 in the circuit of Figure 14.

The first delay circuit 34 and the vertical and temporal filter bank arrangement 35 supply outputs to a selection matrix 37, which also receives a control signal from the adaption filter and control generator arrangement 33, and supplies an output by way of a band-pass filter 38 to a colour demodulator 39. In the by-pass path the second delay circuit 36 supplies an output to a subtracter 40 which also receives an input from the band-pass filter 38, and supplies an output to a third delay circuit 41.

The operation of this part of the system will now be further described. Depending on the content of the input digital video signal, the output of the comparator 18 (Figure 14) indicates whether vertical or vertical/temporal filtering gives the lower cross-talk and hence is preferred for the separation of the luminance and chrominance components, or alternatively whether the cross-talk exceeds the predetermined permissible level set by the threshold level supplied to the input 19 (Figure 14), in which case the by-pass mode using horizontal filtering is to be used. In the former cases, the chrominance component C_V derived from a vertical filter in the vertical and temporal filter bank 35 is selected by the selection matrix 37 for supply by way of the band-pass filter 38 to the colour demodulator 39, or the chrominance component C_T derived from a vertical/temporal filter in the vertical and temporal filter bank 35 is selected by the selection matrix 37 for supply by way of the band-pass filter 38 to the colour demodulator 39. In either event, the output of the band-pass filter 38 is also supplied to the subtracter 40, where the selected chrominance component C_V or C_T is subtracted from the luminance plus chrominance components, so that the output of the subtracter 40 is the luminance component after effectively having been subjected to the complementary vertical or vertical/temporal

filtering.

In the latter case, that is in the by-pass mode, the selection matrix 37 supplies the luminance plus chrominance components from the first delay circuits 34 to the band-pass filter 38, the characteristics of which are selected to effect horizontal filtering to select the chrominance component for supply to the colour demodulator 39 generally as in standard PAL decoding. In this event also, the output of the band-pass filter 38 is also supplied to the subtracter 40, where the horizontally filtered chrominance component is subtracted from the luminance plus chrominance components, so that the output of the subtracter 40 is the luminance component effectively having been subjected to the complementary horizontal filtering.

The use of complementary horizontal filtering, as described immediately above, in the by-pass mode, may have an adverse effect on the luminance resolution, dependent upon the width of the pass band of the band-pass filter 38. An alternative method of using the adaptive control for by-pass selection is to disable the band-pass filter's output into the subtractor 40 by providing a disable circuit 51. Zeros are supplied by the disable circuit 51 to the input to the subtractor 40 when an adaption control is supplied to an input 52, thereby effectively allowing the digital composite signal through the subtractor 40 unfiltered. A colour trap or notch filter 53 is then inserted into the by-pass path when an adaption control is supplied to an input 54. The centre frequency of the notch filter 53 is situated at the sub-carrier frequency, so the notch filter 53 attenuates the major colour component, and therefore less severe restraints are imposed on the luminance resolution. This operation in effect is more nearly equivalent to standard PAL decoding using horizontal filtering. Moreover, it is also possible to select the notch filter 53 via adaption filter comparison in order to alleviate the sub-carrier residue evident when using vertically or vertically/temporally based comb filtering.

The vertical and temporal filters used in the vertical and temporal filter bank 35 are preferably selected from those having characteristics as described above with reference to Figures 9 to 12. The adaption filters used in the adaption filters and control generator arrangement 33 preferably have characteristics as described above with reference to Figure 13. Other forms of vertical, vertical/temporal, temporal and adaption filters may, however, be used. The delays τ_A and τ_B of the first and second delay circuits 34 and 36 are selected to equalize the signal delays in the respective paths.

The colour demodulator 39 supplies outputs to low-pass filters 42 and 43, the outputs of which are connected to a sample reduction and multiplex arrangement 44. The output of the sample reduction and multiplex arrangement 44 is supplied to a U/V chrominance component array generator 45, the output of which is connected by way of a selection matrix 46 to one input of a vertical and temporal filter bank arrangement 47, which as a second input receives a second output from the U/V chrominance component array generator 45 by way of a by-pass path. The output of the vertical and temporal filter bank arrangement 47 is connected by way of a filter selector 48 to a blanking and synchronization signal insertion arrangement 49, which also receives an input from the third delay circuit 41, and supplies a digital output comprising alternating luminance and chrominance samples to an output 50.

The operation of this remaining part of the system will now be further described. Having achieved the separation of the luminance and chrominance components, this part of the system operates to derive the base band U and V chrominance components. This is done by multiplying the chrominance waveform by appropriately phased sub-carrier waveforms. To do this it is necessary digitally to generate sub-carrier phase values and consequently amplitude values, based on the line lock sampling frequency of 13.5 MHz. This can be done using sample and line counters which address programmable read only memories (PROMS) which store specific values of sub-carrier phase according to the sample to sub-carrier relationship. The sub-carrier phase values held in the PROMs are repetitive on a line-by-line basis, so the line phase offsets can be derived by the modulo addition of specific line phase values. It is also necessary to ensure synchronization with the demodulated burst signals in the incoming signal, these being used to derive an error measurement with which to bring a loop into lock. Having achieved synchronism, the phase values are converted to required sine and cosine amplitude values for supply to U and V chrominance component demodulation multipliers in the colour demodulator 39. The low-pass filters 42 and 43 derive the U and V base band components from the resulting demodulation products.

It is also necessary to ensure that the chrominance component is demodulated with the correct V phase. This is done in known manner, for example using the properties of Bruch blanking.

It is also possible, although this is not an essential feature, that adaptive decoding is applied to the separation of the U and V chrominance components in addition to the adaptive decoding described above for separation of the luminance and chrominance components. This will now be further described.

Firstly, sample rate reduction is carried out for both the U and V channels. This is possible because the sampling rate of 13.5 MHz is greater than twice the Nyquist frequency for the chrominance bandwidths. This sample rate reduction effectively makes the sampling rate 6.75 MHz for each of the U and V chrominance components. This reduction is effected by the sample reduction and multiplex arrangement 44, which further multiplexes the resulting samples for supply to the U/V chrominance component array generator 45, which comprises two line stores and two field stores.

The adaptive decoding process is similar in form and operation to that described above for the luminance and chrominance separation, but is substantially simpler. Thus the U/V chrominance component array generator 45 need only derive five of the samples shown in the array of Figure 8, these

being the samples E, K to M and R shown in Figure 16 and corresponding to three fields of the video signal.

In order to decide on the mode of chrominance separation to be selected, the cross-talk again has to be detected, and this is done by means of further adaption filters, which may be generally as described above for the luminance/chrominance separation. In the same manner as described, the adaption filters can be used to determine whether vertical, vertical/temporal, temporal or horizontal filtering is preferred for separation of the U and V chrominance components.

The vertical and temporal filter bank arrangement 47 is generally similar in operation to the vertical and temporal filter bank arrangement 35, but can be substantially simpler in particular because the separation of the U and V chrominance components is less critical than the separation of the luminance and chrominance components.

Figure 17 shows the vertical/temporal characteristic of a field based temporal filter for U/V chrominance separation, based on sample points in the array of Figure 16 and using E/4+L/2+M/4. Figure 18 shows the vertical/temporal characteristic of a line based vertical filter for U/V chrominance separation, using K/4+L/2+M/4. In each case the broken-ended rectangles indicate the filter pass-band.

The delay τ_C of the third delay circuit 41 compensates for the delay to the U and V chrominance components, so that finally the filtered multiplexed U and V components and the luminance component are supplied to the blanking and synchronization signal insertion arrangement 49 where the blanking and synchronizing information is digitally added and the components are further multiplexed so that the samples are supplied in the sequence Y, C_B, Y, C_R . . . to the output 50 at a frequency of 27 MHz.

CLAIMS

1. A method of decoding an orthogonally sampled, composite digital PAL video signal, the method comprising the steps of:
measuring the cross-talk between luminance and chrominance components in said video signal resulting from movement in the picture represented by said video signal; and
switching between vertical filtering, temporal filtering, vertical/temporal filtering and horizontal filtering for separation of the chrominance component of said video signal from the luminance component of said video signal in dependence on the result of said measurement, so as to reduce cross effects resulting from said cross-talk.

2. A method according to claim 1 wherein said measurement is performed sample by sample of said vidědo signal.

3. A method according to claim 2 wherein said switching is smoothed by averaging the results of said measurement over a plurality of said samples of said video signal.

4. A method according to claim 1, claim 2 or claim 3 comprising the further steps of:
further measuring the cross-talk between demodulated U and V chrominance components derived from said separated chrominance component and resulting from movement in the picture represented by said video signal; and
switching between vertical filtering, temporal filtering and horizontal filtering, for separation of said U and V chrominance components in dependence on the result of said further measurement, so as to reduce cross effects resulting from said chrominance cross-talk.

5. Apparatus for decoding orthogonally sampled, composite digital PAL video signals, the apparatus comprising:
means for measuring the cross-talk between luminance and chrominance components of said video signal resulting from movement in the picture represented by said video signal; and
means for switching between vertical filtering, temporal filtering, vertical/temporal filtering and horizontal filtering for separation of the chrominance component of said video signal from the luminance component of said video signal in dependence on the result of said measurement, so as to reduce the cross effects resulting from said cross-talk.

6. Apparatus according to claim 5 wherein said means for measuring the cross-talk comprises a line filter and a field filter to each of which said video signal is supplied, and a comparator for comparing the energy outputs of said line and field filters.

7. Apparatus according to claim 6 wherein said line filter differences the samples in corresponding positions in the lines preceding and succeeding a given line in a field of said video signal.

8. Apparatus according to claim 6 or claim 7 wherein said field filter differences adjacent diagonally disposed samples in adjacent lines in the field preceding or following a given field of said video signal.

9. Apparatus according to any one of claims 5 to 8 further comprising:
a demodulator for deriving demodulated U and V chrominance components from said separated chrominance component;
means for further measuring the cross-talk between said demodulated U and V chrominance components and resulting from movement in the picture represented by said video signal; and
means for switching between vertical filtering, temporal filtering and horizontal filtering for separation of said U and V chrominance components in dependence on the result of said further measurement, so as to reduce cross effects resulting from said chrominance cross-talk

10. A method of decoding an orthogonally sampled digital PAL video signal, the method being

substantially as hereinbefore described with reference to the accompanying drawings.

11. Apparatus for decoding an orthogonally sampled digital PAL video signal, the apparatus being substantially as hereinbefore described with reference to the accompanying drawings.

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